Today

- Announcements:
  - The average on the first exam was 31/40
  - Exam extra credit is due by 8:00 am Wednesday February 13th.
  - The second homework extra credit is due by Wednesday February 13th.
- F=ma
- Electric Force
- Work, Energy and Power
Newton’s Second Law of Force

\[ F = ma \]

An equation is worth greater than half the words of a picture.

- Force is equal to mass times acceleration.
- For a given force, the amount of acceleration is inversely proportional to the mass.
- Force causes acceleration.
- If you observe acceleration, there must be a force acting.
A new Force!

- Charge is a property of matter. It is measured in Coulombs C.
- Like charges repel, unlike charges attract.
- Coulomb’s Law of Electric Force

\[ F = \frac{kQ_1Q_2}{r_{12}^2} \quad k = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \]
Why?

- Coulomb’s law looks like Newton’s Law of gravity. Why?
- Why does charge come in two types and mass only came in one type?
- Why do we always get \( r^2 \)? I hate squares.
- Why is \( k = 8.99 \times 10^9 \text{ Nm}^2/\text{C}^2 \) so much bigger than \( G = \text{Nm}^2/\text{kg}^2 \)?

Two possible answers:
(1) I can’t tell you until you are older. (2) I don’t know.
Energy

• Energy is the ability to do work
• Energy comes in two forms
  – Kinetic (KE) – energy of motion
  – Potential (PE) – energy of position
• There are many variants on these type main types, e.g. chemical, nuclear, thermal, …
Energy and Power

• Energy is the ability to do work: Work = force x distance = F d

• Energy comes in two forms
  – Kinetic (KE) – energy of motion
  – Potential (PE) – energy of position
  Gravitational GPE = m (gh); g = 9.81 m/s² on Earth, h height

• Power (measured in W = J/s) is the rate of change (or use) of energy

\[ KE = \frac{1}{2}mv^2 \]

m - mass
v - velocity
Some Example Problems

Examples:

• A mass of 1.0 kg is raised 1.0 m. How much work was done?
  \[ W = \Delta GPE = mg\Delta h = 1.0 \text{ kg} \times 9.81 \text{ m/s}^2 \times 1.0 \text{ m} = 9.81 \text{ J} \]

• A 90.0 kg ISP209 professor walks up two flights of stairs. How much did his/her potential energy increase? DATA 1 flight of stairs = 3.00 m
  \[ \Delta GPE = 90.0 \text{ kg} \times 9.81 \text{ m/s}^2 \times 2 \text{ flights} \times (3 \text{ m/flight}) = 5.29 \text{ kJ} \]
Conservation of Energy

In nature certain quantities are “conserved”. Energy is one of these quantities. Charge is another.

**Example: Ball on a hill**

A 1.00 kg ball is rolled toward a hill with an initial speed of 5.00 m/s. If the ball rolls without friction, how high, h, will the ball go?

\[
KE = \frac{1}{2}mv^2 \quad PE = mgh \quad g = 9.80 \frac{m}{s^2}
\]

\[
\frac{1}{2}mv^2 = mgh \rightarrow h = \frac{v^2}{2g} = \frac{(5\ m/s)^2}{2 \cdot 9.80 \frac{m}{s^2}} = 1.28\ m
\]
Work

- Work = Force \times distance
- Work is a scalar and is measured in Joules, J
- Bill pushes on a wall with 10 N for 33 s. If the wall does not move, how much work is done on the wall?
  - Work = 10.0 N \times 0.0 m = 0.0 N
- How does that make sense? Work has a strict definition. If the kinetic or potential energy of the wall did not change, no work was done on the wall.
- Work changes energy from one form to another.
Power

- Power is the rate of change of energy
- Power = (change in energy)/(change in time)
- Power is a scalar and is measured in watts.
- Light bulbs are measured in watts
- Sun (a big light bulb) - $3.827 \times 10^{26}$ W
Information

- Horsepower 746 W = 1 horsepower
  In fourteen hundred and ninety-two
  Columbus sailed the ocean blue.
  And if you divide by two
  You get watts in a horsepower too

- Food energy is measured in kcal
  - 1 food cal = 4.184 J
  - 1 Calorie = 1 kcal  (what we call calories are actually kilocalories)
Example Problem

How many kcal are burned by doing 1500 J of work?

DATA: The human body is 10% efficient in converting food energy to work.

\[
\text{cal} = \text{energy} \cdot \frac{1 \text{ cal}}{4.184 \text{ J}} \cdot \left( \frac{1}{\text{efficiency}} \right)
\]

\[
1500 \text{ J} \cdot \frac{1 \text{ cal}}{4.184 \text{ J}} \cdot \left( \frac{1}{0.1} \right) = 3590. \text{cal} = 3.59 \text{ kcal}
\]